

## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.7 ELECTRICAL AND COMMUNICATIONS EQUIPMENT

#### 6.4.7.2 EMERGENCY GENERATORS

Emergency generators are essential for postearthquake operations for many types of facilities. These range from small residential size generators to large systems required to maintain hospital or other essential operations. Emergency generators are often mounted on vibration isolators.

#### TYPICAL CAUSES OF DAMAGE

- Emergency generators may slide, tilt, or overturn. Internal elements may be damaged by inertial forces.
- Unanchored or poorly reinforced housekeeping pads may fail, resulting in excessive movement of the supported equipment.
- Vibration isolators can fail causing excessive generator movement.
- Failure of the emergency power generating system may be caused by the failure of any of the component parts including generator, fuel tank, fuel line, batteries and battery racks.

#### SEISMIC MITIGATION CONSIDERATIONS

- Working around electrical equipment can be extremely hazardous. Read the Electrical Danger Warning and Guidelines in Section 6.6.8 of this document before proceeding with any work.
- Many equipment items can be supplied with a structural steel base, shop welded brackets, or predrilled holes for base anchorage. For any new equipment, request items that can be supplied with seismic anchorage details.
- For equipment mounted on a free-standing concrete pad, make sure pad is large enough to resist seismic overturning of generator.
- Check the anchorage for all the component parts of the emergency power generation system; failure of any one of them could compromise the postearthquake performance of the system. Provide flexible connections for the fuel line, exhaust ducting and any other connected utility.

- See Section 6.4.1.1 for additional base anchorage details. Refer to FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) for general information on seismic anchorage of electrical equipment.

### Mitigation Examples



Figure 6.4.7.2-1 Emergency generator is anchored to a concrete inertia base. The inertia base is mounted on spring isolators and restrained by steel angle snubbers on all sides (Photo courtesy of Maryann Phipps, Estructure).



Figure 6.4.7.2-2 Emergency generator with skid mount on housekeeping pad; shear lugs added following the 2001 Peru Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).

## Mitigation Details

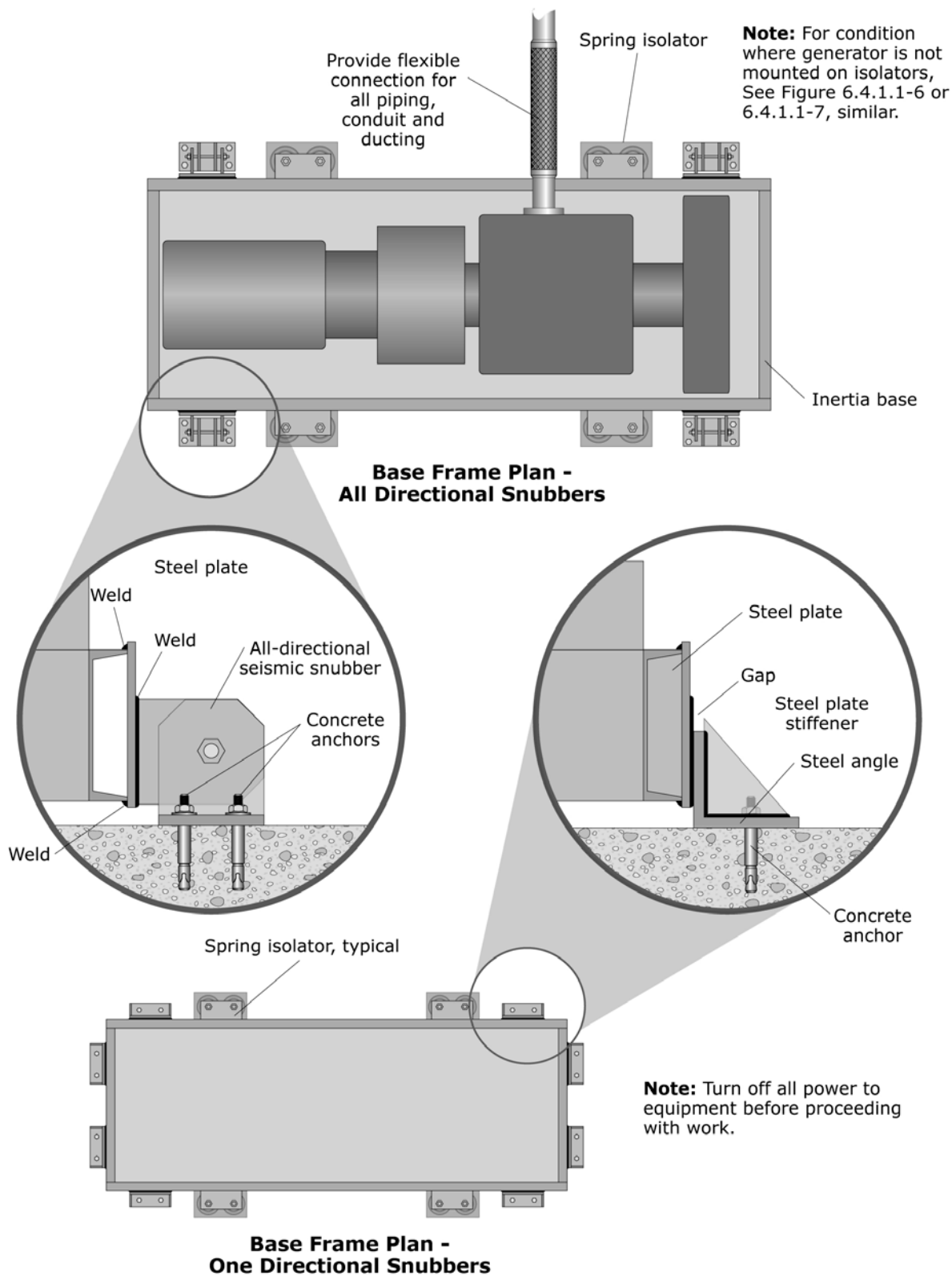


Figure 6.4.7.2-3 Emergency generator (ER).



## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.7 ELECTRICAL AND COMMUNICATIONS EQUIPMENT

#### 6.4.7.3 TRANSFORMERS

Transformers may be dry-type or liquid filled; mounted on a floor, wall or roof; and installed with or without vibration isolation.

#### TYPICAL CAUSES OF DAMAGE

- Transformers may slide, tilt, overturn, or fall. Vibration isolation hardware may be damaged.
- Internal elements may be damaged by inertial forces.
- Damaged electrical equipment may be cause electrical hazards and fire hazards. Transformer damage may result in power outages and business interruption.

#### Damage Examples

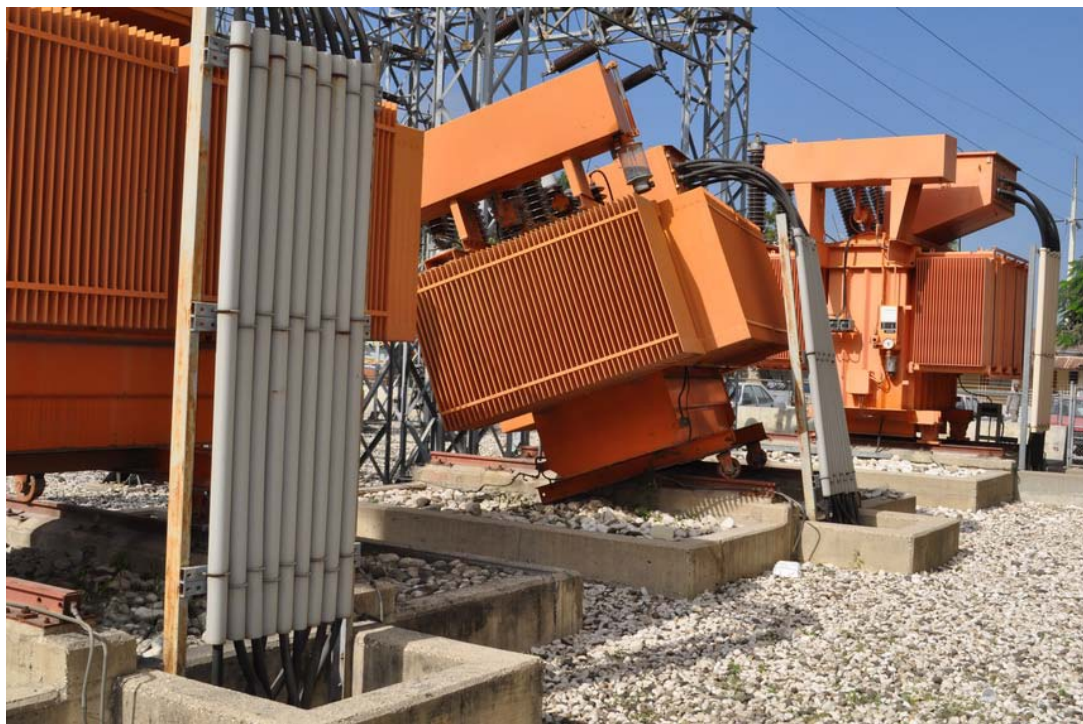


Figure 6.4.7.3-1 Rail mounted transformer slipped off rails at power plant in Port-au-Prince in the 2010 magnitude-7 Haiti Earthquake; only one of six identical transformers was damaged (Photo courtesy of Eduardo Fierro, BFP Engineers).

## SEISMIC MITIGATION CONSIDERATIONS

- Working around electrical equipment can be extremely hazardous. Read the Electrical Danger Warning and Guidelines in Section 6.6.8 of this document before proceeding with any work.
- This type of equipment can be supplied with a structural steel base, shop welded brackets, or predrilled holes for base anchorage. For any new equipment, request items that can be supplied with seismic anchorage details.
- See Section 6.4.1.1 for additional base anchorage details. Refer to FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) for additional mounting configurations such as wall- and roof-mounting, or vibration isolation as well as general information on the seismic anchorage of electrical equipment.

## Mitigation Details

**Note:** Turn off all power to equipment before proceeding with work

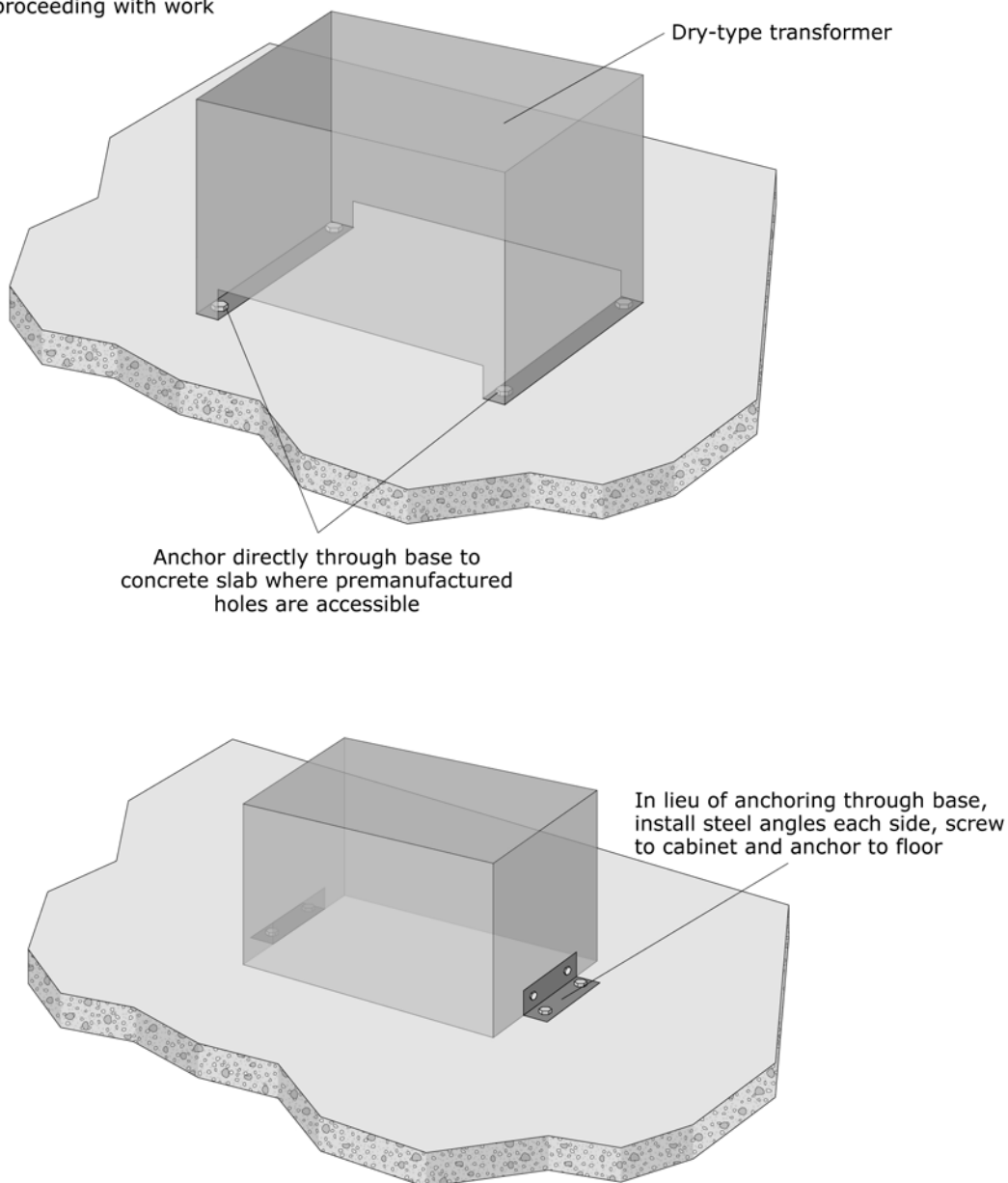


Figure 6.4.7.3-2 Transformer (ER).

## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.7 ELECTRICAL AND COMMUNICATIONS EQUIPMENT

#### 6.4.7.4 BATTERIES AND BATTERY RACKS

This category covers batteries and battery racks, often used as part of the emergency generation system. These may be mounted on a concrete floor, raised floor, wall or roof.

#### TYPICAL CAUSES OF DAMAGE

- The racks may slide or overturn and batteries may slip or fall from the rack. Failure of the batteries may compromise the emergency power generation system or other functions that rely on backup battery power.

#### Damage Examples

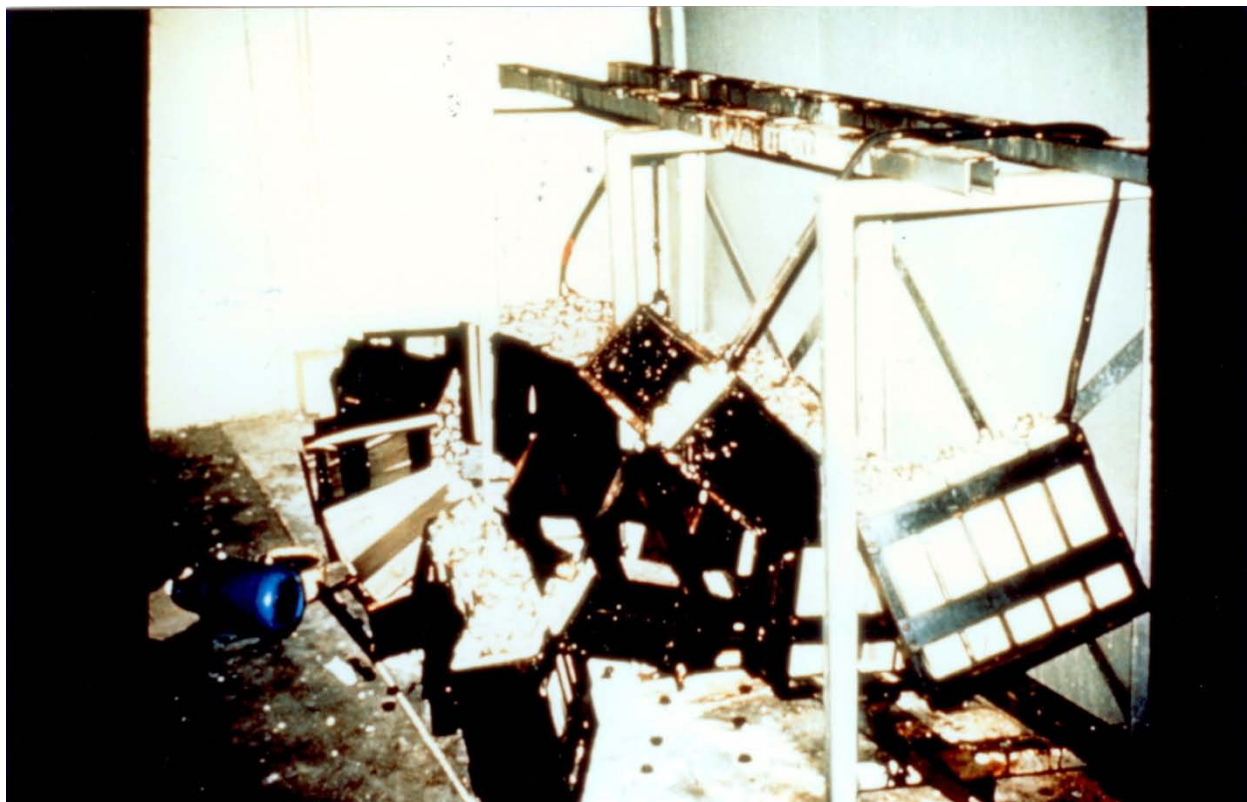


Figure 6.4.7.4-1 Earthquake Damage in the 1971 magnitude-6.6 San Fernando Earthquake (Photo courtesy of John F. Meehan).



## SEISMIC MITIGATION CONSIDERATIONS

- Seismic resistant battery racks are available from a number of vendors; these may be directly bolted to the floor or wall. Check the internet for available products.
- For existing battery racks, check that the batteries are secured to the rack and that the rack is properly braced and anchored.

### Mitigation Examples



Figure 6.4.7.4-2 Anchored battery racks (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.7.4-3 Batteries anchored with equipment skid (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.7.4-4 Battery rack that performed well in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Rodrigo Retamales, Rubén Boroschek & Associates).

## Mitigation Details

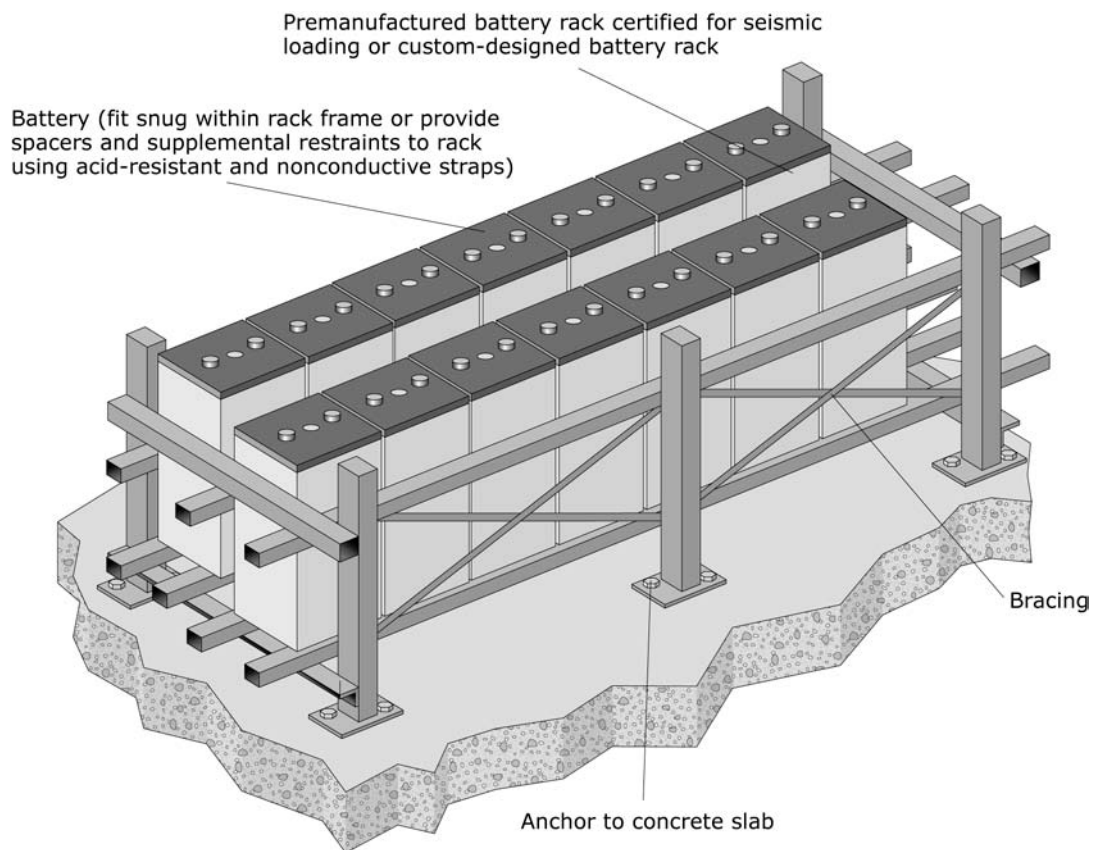


Figure 6.4.7.4-5 Batteries and rack (ER).

## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.7 ELECTRICAL AND COMMUNICATIONS EQUIPMENT

#### 6.4.7.5 PHOTOVOLTAIC (PV) POWER SYSTEMS

This category covers photovoltaic (PV) power systems and solar car charging stations, commonly mounted on roofs or on separate freestanding racks.

#### TYPICAL CAUSES OF DAMAGE

- As the installation of these fixtures on U.S. rooftops is relatively new, there are few documented examples of earthquake damage to date. This is in part due to the fact that since panels tend to be very light, the most severe design loading for roof-mounted photovoltaic panels is typically wind. Nevertheless, if these have not been properly designed to meet seismic loading, the panels may become dislodged and fall from the racks or fall off of pitched roofs or piping may be damaged, resulting in leakage. Wiring may also become dislodged and disable the systems.

#### SEISMIC MITIGATION CONSIDERATIONS

- Solar power is a rapidly changing field; these products and systems are evolving. Where existing photovoltaic systems may weigh between 2.5 to 3.0 pounds per square foot and consist of glass covered modules that are roof mounted on aluminum or galvanized steel track, newer products include lighter panels without glass, solar roof tiles that interlock with standard S-shaped clay or concrete roofing tiles, or peel and stick panels which weigh under 2 pounds per square foot that may be applied directly to the roof surface. Several of these newer systems are integrated with the roofing materials and may not require special seismic consideration as long as the additional weight is accounted for. Ballasted photovoltaic systems are also available that do not require anchorage or penetration of the roofing membrane. Check the internet for proprietary systems.
- Photovoltaic panels supported on framing systems are typically flush mounted or tilt mounted. These systems typically have anodized aluminum or galvanized steel track channels mounted to brackets or standoffs which are mounted to roof framing or structural supports. The panels or modules are then screwed directly to the track,



typically four per panel. For installation on a wood framed roof, the system layout works best when the track is mounted perpendicular to the rafters; blocking may be required between the rafters where the track is mounted parallel to the rafters. Care must be taken to see that the roof penetrations are well sealed so the photovoltaic power system does not cause roof leaks. Friction fittings should not be used to resist seismic loading; positive connections should be provided between all the component parts.

- Photovoltaic power systems may be installed on top of carports for charging electric cars. Before mounting an expensive solar system on top, it must be ensured that the carport or patio structures have been designed for seismic loading.
- The State of California has published DSA IR 16-8 *Solar Photovoltaic and Thermal Systems Acceptance Requirements* (California Department of General Services, 2010a) to address requirements for California schools. This document describes solar systems supported on framing systems and foundations, ballast panel systems, and adhered panel systems.
- Installation guidelines are available on the internet for proprietary flush mount kits and tilt up kits. For example, UniRac, Inc. has installation manuals for two proprietary systems called SolarMount and Clicksys (see <http://unirac.com/mounting-solutions>). These installation manuals have wind and snow load tables with wind loading from 90 mph to 170 mph. Although there is no explicit mention of seismic provisions, the detailing will be adequate if designed sufficiently for wind. A review of the tabulated wind design loads shows these systems are engineered for 10 psf to over 100 psf uplift; thus a well engineered wind design for a photovoltaic system typically weighing less than 3 psf should not require additional seismic detailing. Another company, Professional Solar Products (<http://www.prosolar.com/prosolar-new/pages/installation-guides-subpage2.htm>) has hardware with installation guides for tilt up kits designed for 30 psf or 100 mph winds.
- Like any components exposed to the weather, components and connectors for photovoltaic systems should be corrosion resistant materials such as stainless steel or anodized aluminum. Where roof penetrations are required, these should have appropriate flashing and caulking to prevent leakage.



## Mitigation Examples

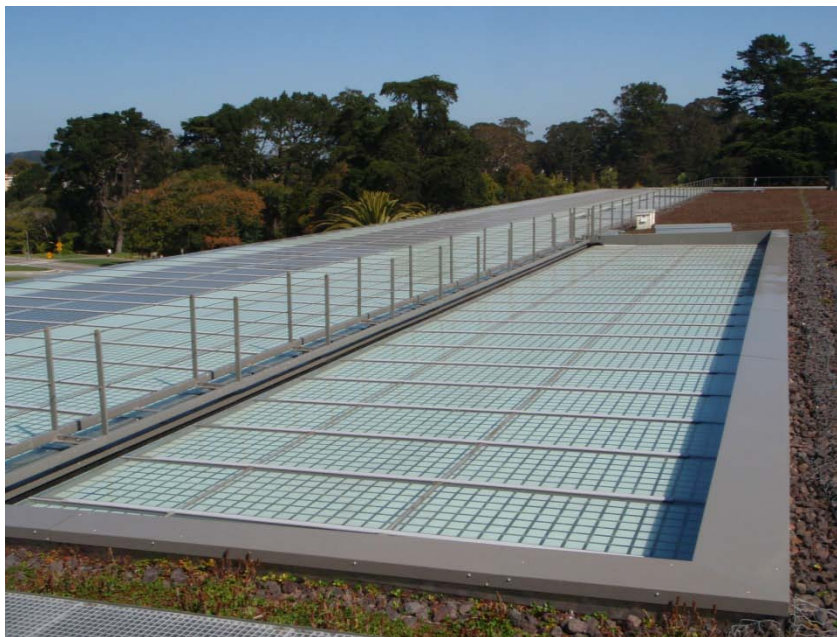


Figure 6.4.7.5-1

60,000 photovoltaic cells are incorporated into the glass canopy surrounding the Academy of Science, San Francisco, California (Photos courtesy of Cynthia Perry, BFP Engineers). The photovoltaic system provides 10% of the electricity needed for the facility. Panels must be securely attached to resist wind loads but also because these cantilevered members may be subject to vertical as well as horizontal seismic forces.

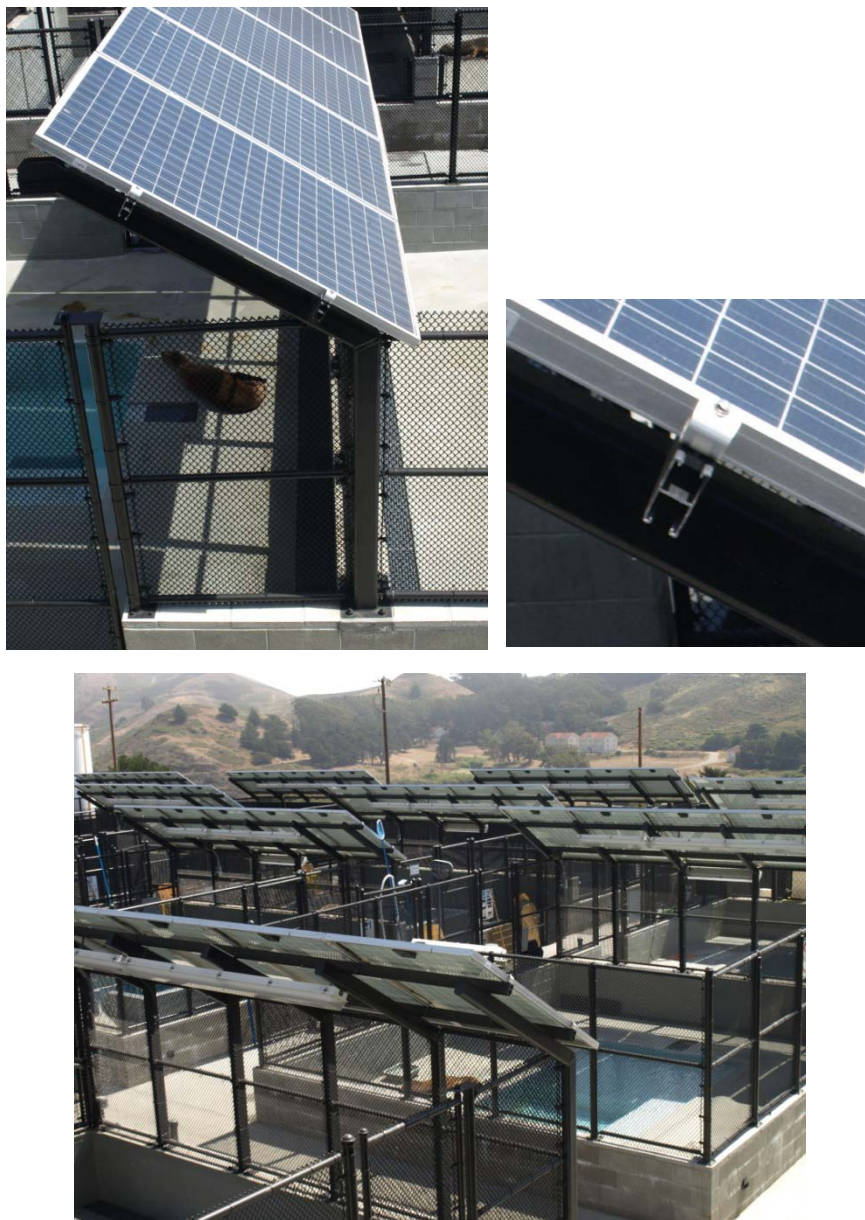


Figure 6.4.7.5-2 Ground mounted photovoltaic system that also provides shade to injured animals at the Marine Mammal Center in Sausalito, California (Photo courtesy of Cynthia Perry, BFP Engineers). Each solar panel is screwed to the strut at four locations; two rows of struts are bolted to 6 steel tubes which are anchored at the base with four bolts apiece.



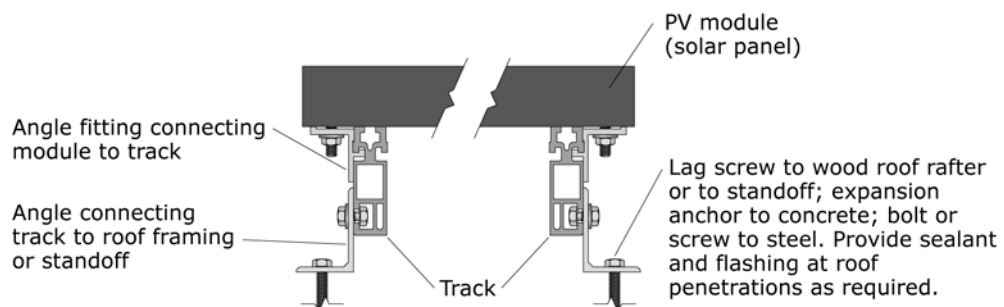
Figure 6.4.7.5-3 Residential photovoltaic system in Berkeley, California mounted over the transition between two different roof slopes (Photos courtesy of Heber Santos). Short standoff used on tar and gravel flat portion (upper left); aluminum flashing and mounting bracket used on sloped portion with composition tile roofing (upper right). The profile of one type of proprietary mounting track is seen at lower left.



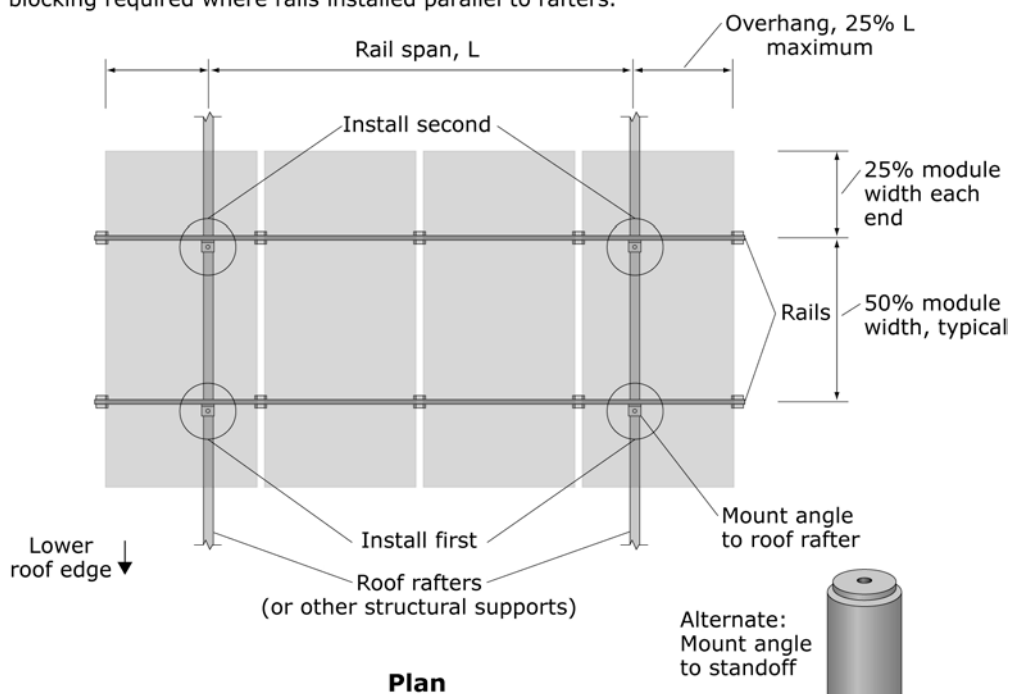


Figure 6.4.7.5-4 Flush mount photovoltaic system on barrel shaped roof of gymnasium at Head-Royce School, Oakland, California (Photo courtesy of Cynthia Perry, BFP Engineers).

## Mitigation Details



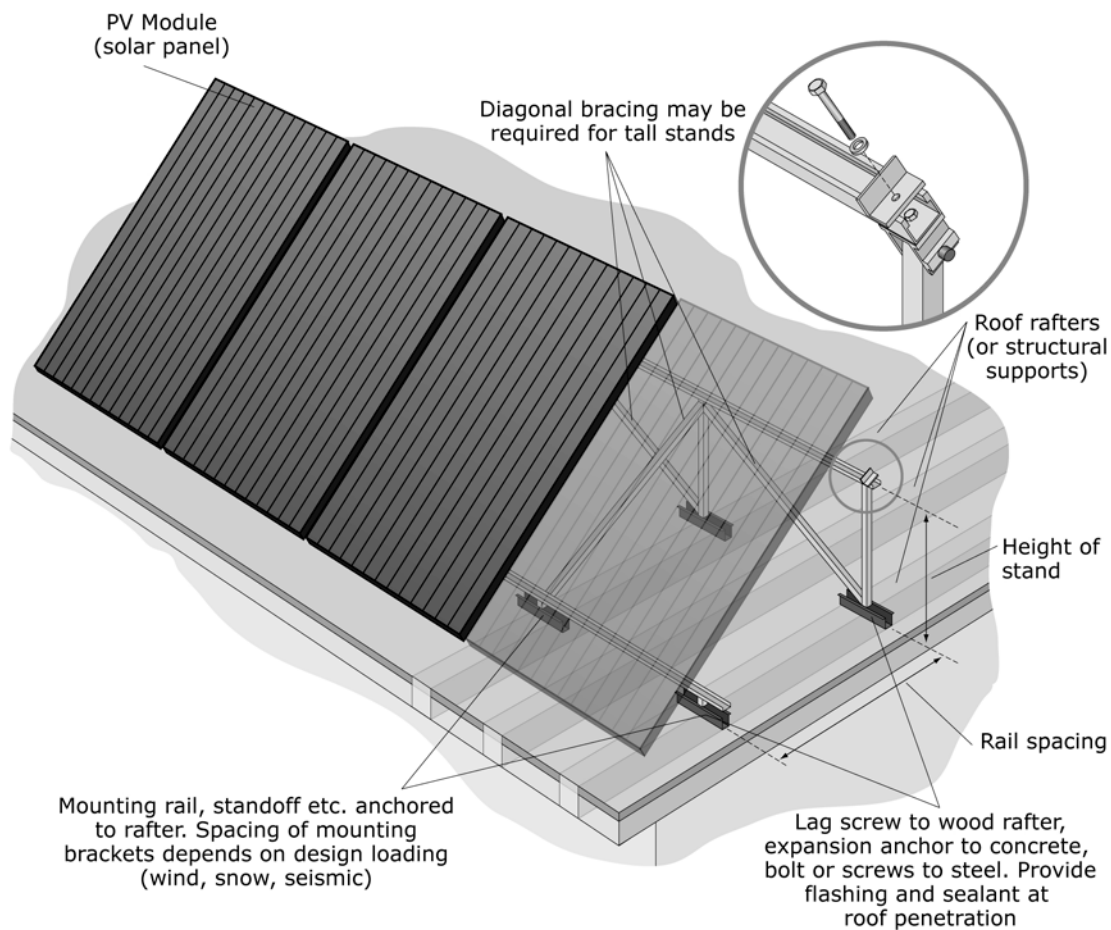
**Note:** Track shown perpendicular to rafters. Wood blocking required where rails installed parallel to rafters.



**Note:** All components should be corrosion resistant such as anodized aluminum or stainless steel. Proprietary flush mount kits available with sizes and spacing pre-engineered for various wind loads.

Figure 6.4.7.5-5 Typical details for flush-mounted photovoltaic power modules (ER).





**Note:** All components should be corrosion resistant such as anodized aluminum or stainless steel. Proprietary tilt-up kits available with sizes and spacing pre-engineered for various wind loads.

Figure 6.4.7.5-6 Typical tilt up details for anchored photovoltaic power modules (ER).

## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.7 ELECTRICAL AND COMMUNICATIONS EQUIPMENT

#### 6.4.7.6 COMMUNICATIONS ANTENNAE

This category covers communications antennae, often referred to as satellite dishes, which may be mounted in a variety of ways. Circular antennae used for residential or small commercial applications are typically supported by a single mast that may be mounted on a wall, roof, chimney, eaves, balcony, or freestanding at the ground. Non-penetrating roof mounts that typically rely on ballast are also available.

#### TYPICAL CAUSES OF DAMAGE

- While TV antennae have been mounted on roofs for many decades, the appearance of circular antennae on U.S. rooftops is relatively new, and to date, earthquake damage has not been documented. This is in part due to the fact that since antennae tend to be very light, the most severe design loading for circular antennae is typically wind. Nevertheless, if antennae have not been mounted to meet seismic loading, they could become dislodged and either the dish or the mast or both could fall.
- Damage to the antennae could disable critical communications systems or television access that may be needed following an earthquake.

## Damage Examples



Figure 6.4.7.6-1 Most antenna are designed for wind and able to resist seismic loading. In spite of the collapse of the first story of this residential building complex, the roof-mounted antennae appear intact in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.7.6-2      Antennae retrieved from roof of adjacent collapsed wing of the Hôpital Saint-François de Sales in the 2010 magnitude-7 Haiti Earthquake (not known if antenna suffered earthquake damage; photo courtesy of Ayhan Irfanoglu, Purdue University). Hospital communications depend on the functionality of antennae such as this.





Figure 6.4.7.6-3 Damage or movement of ballasted antennae was not observed on this rooftop in the 2010 magnitude-6.5 Eureka Earthquake (Photo courtesy of Maryann Phipps, Estructure).



Figure 6.4.7.6-4 The antenna with guy wires remained upright atop a collapsed building in the 2010 Haiti Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers). Even though some of the guy wires went slack, the antenna did not fall into the street.



## SEISMIC MITIGATION CONSIDERATIONS

- The Federal Communications Commission (FCC) issues regulations for Over-the-Air Reception Devices to preempt restrictions on the size, mast height, or location of direct-to-home satellite dishes. For instance, Title 47 (Section 1.200) of Code of Federal Regulations which codifies the FCC regulations covers dishes less than 1 meter in diameter with a mast height less than 12 feet above the roofline. In addition, tenant or homeowner association agreements may have restrictions on the size or placement of antennae; check for local code or association requirements.
- The antenna mast may be mounted in a variety of ways, for example to wood or metal stud walls, concrete or solid masonry walls (cells filled with concrete), hollow masonry block walls, freestanding poles, or to roof rafters or a concrete roof slab. Schematic details for installing the mast mounting bracket to a stud or concrete walls are shown in Figure 6.4.7.6–5.
- Some mounting kits available on the internet provide hardware for strapping the antenna to a residential chimney. As unreinforced masonry chimneys are highly prone to earthquake damage as described in Section 6.3.7.1, antenna should not be mounted to unreinforced masonry chimneys. If the chimney is adequately reinforced, chimney mount details may be used for lightweight antennae.
- Hardware and kits for non-penetrating ballasted mounts are also available for purchase. These kits often use standard sized concrete blocks for ballast. Use of multiple concrete blocks for ballast may be heavy enough to trigger the requirement for the equipment to have engineered anchorage. While these ballasted systems can reasonably be used in areas of low seismicity, they could potentially slide and damage roofing or wiring in areas of high seismicity.
- Large or tall antennae need to be properly engineered for both wind and seismic loading. Tower antennae may be anchored with guy wires, or mounted to a specially designed frame. Positive attachments from the antenna to the supporting structure should be provided and one should check with the manufacturer to see if the antenna itself has been designed or tested for seismic loading since seismic forces at the roof elevation are typically much higher than at ground level.
- Communications equipment used for essential facilities may need to be shake table tested and certified. Shake tables operated by the Pacific Earthquake Engineering Research Center (PEER) at UC Berkeley, MCEER at SUNY Buffalo, and others both perform testing of telecommunications network equipment in accordance with *NEBS*

*Requirements: Physical Protection* (NEBS, 2006), protocol to certify that the internal parts and electronic components can withstand seismic shaking.

- As with any items mounted with exterior exposure, components and connectors should be corrosion resistant and roof or wall penetrations should receive flashing and sealant as appropriate.

### Mitigation Examples



Figure 6.4.7.6-5 Antenna mast mounted to concrete wall surface at top floor of building (Photo courtesy of (Photo courtesy of Maryann Phipps, Estructure). Note that two wall brackets are used to resist moments produced by wind or seismic forces. This antenna is larger than most standard residential versions.



Figure 6.4.7.6-6 Antenna mast mounted to wood stud wall using blocking to clear eaves (Photo courtesy of Cynthia Perry, BFP Engineers).

## Mitigation Details

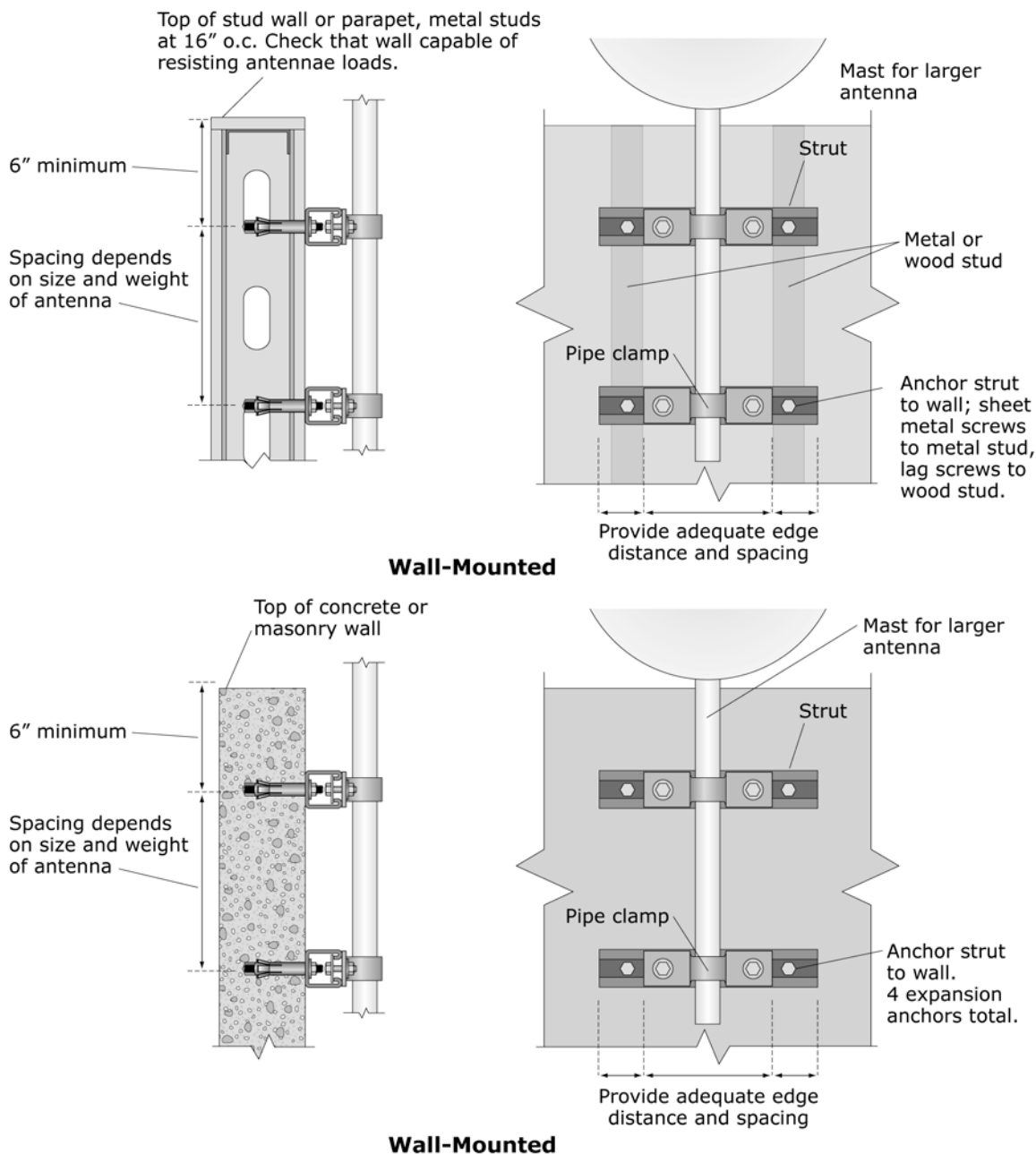
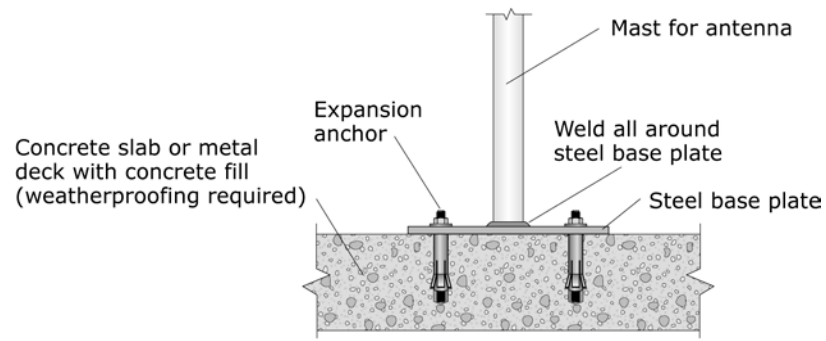


Figure 6.4.7.6-7 Details for wall-mounted communications antenna (ER).



**Cantilevered from base**

Figure 6.4.7.6-8 Details for roof/slab mounted communications antenna (ER).



## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.8 ELECTRICAL AND COMMUNICATIONS DISTRIBUTION EQUIPMENT

#### 6.4.8.1 ELECTRICAL RACEWAYS, CONDUIT, AND CABLE TRAYS

This category covers electrical raceways, conduit, cable trays, and bus ducts. These items may be suspended from above or be floor-, chase-, wall- or roof-mounted.

#### TYPICAL CAUSES OF DAMAGE

- Items may swing and impact structural or other nonstructural elements; they may fall and create electrical hazards.
- Vulnerable locations include seismic separations; wall, floor, or roof penetrations; and attachments to rigidly mounted equipment.

#### Damage Examples



Figure 6.4.8.1-1 Unbraced suspended piping and conduit (Photo courtesy of Wiss, Janney, Elstner Associates).

## SEISMIC MITIGATION CONSIDERATIONS

- Working around electrical equipment can be extremely hazardous. Read the Electrical Danger Warning and Guidelines in Section 6.6.8 of this document before proceeding with any work.
- Two trapeze anchorage details are shown. See Section 6.4.3.1 for additional pipe anchorage details; the same type of bracing is typically used for electrical distribution lines. Refer to FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) for general information on seismic anchorage of electrical equipment and to FEMA 414 *Installing Seismic Restraints for Duct and Pipe* (2004) for many different anchorage configurations for raceways, conduit and cable trays.
- Several engineered seismic bracing systems are available and can be customized for most applications. This is particularly useful for large scale projects or essential applications.

### Mitigation Examples



Figure 6.4.8.1-2 Rigid strut bracing provides restraint against earthquake forces perpendicular to the piping. Similar bracing is required in the direction parallel to the conduit (Photo courtesy of Maryann Phipps, Estructure).



Figure 6.4.8.1-3 Rigid strut bracing for trapeze supporting electrical conduit; conduit attached to trapeze with conduit clamp that provides lateral and longitudinal restraint (Photo courtesy of Maryann Phipps, Estructure).





Figure 6.4.8.1-4 Lateral and longitudinal rigid strut bracing for trapeze supporting electrical raceways (Photo courtesy of Maryann Phipps, Estructure).

### Mitigation Details

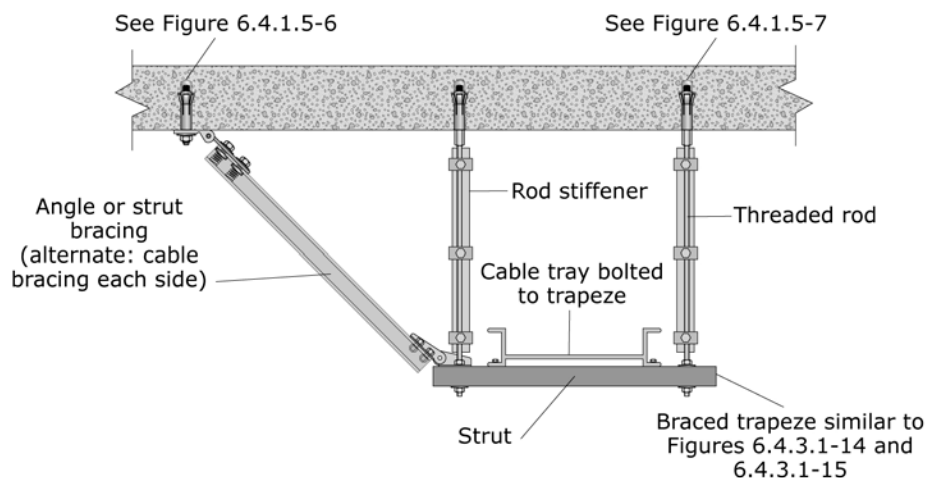


Figure 6.4.8.1-5 Cable tray on braced trapeze (ER).



## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.8 ELECTRICAL AND COMMUNICATIONS DISTRIBUTION EQUIPMENT

#### 6.4.8.2 ELECTRICAL DISTRIBUTION PANELS

This category includes electrical distribution panels, either recessed or surface-mounted. Wall-mounted electrical panels have generally performed well in past earthquakes, in part due to their weight (typically less than 200 pounds), the ductility of the sheet metal cabinets, and the strength of the interconnected conduit which can serve as unintended bracing.

#### TYPICAL CAUSES OF DAMAGE

- Panels may become dislodged and fall.
- Damage to distribution panels and the attached lines may create electrical hazards and fire hazards.

## Damage Examples

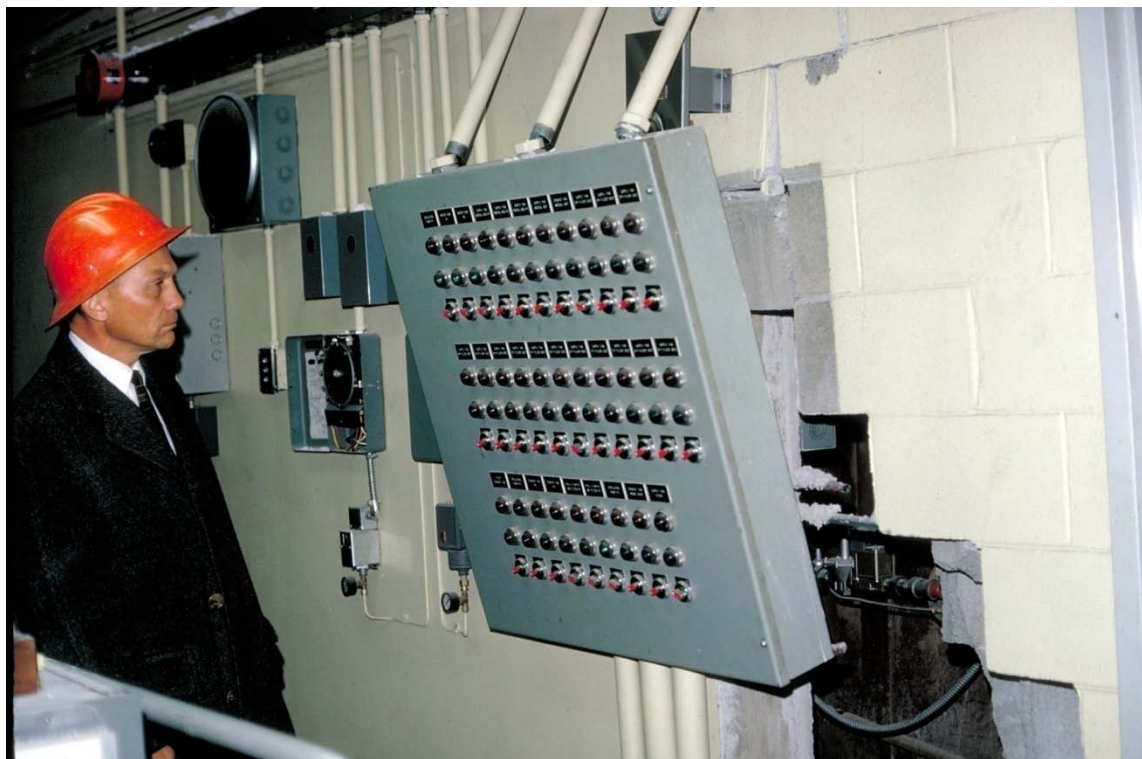


Figure 6.4.8.2-1 Dislodged panel board due to failure of hollow concrete block partition wall in the 1964 magnitude-9.2 Anchorage, Alaska earthquake (Photo courtesy of PEER Steinbrugge Collection, No. S2144).

## SEISMIC MITIGATION CONSIDERATIONS

- Working around electrical equipment can be extremely hazardous. Read the Electrical Danger Warning and Guidelines in Section 6.6.8 of this document before proceeding with any work.
- This type of equipment can be supplied with shop welded brackets or predrilled holes for wall anchorage. For any new equipment, request items that can be supplied with seismic anchorage details.
- See Section 6.4.7.1 for additional details. The wall mount detail shown is for a concrete wall; refer to FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) for additional information about anchoring to masonry or drywall and for general information on seismic anchorage of electrical equipment.

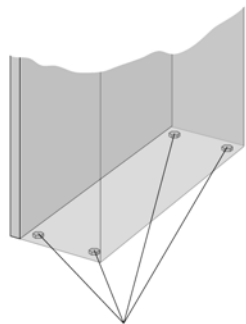
## Mitigation Examples



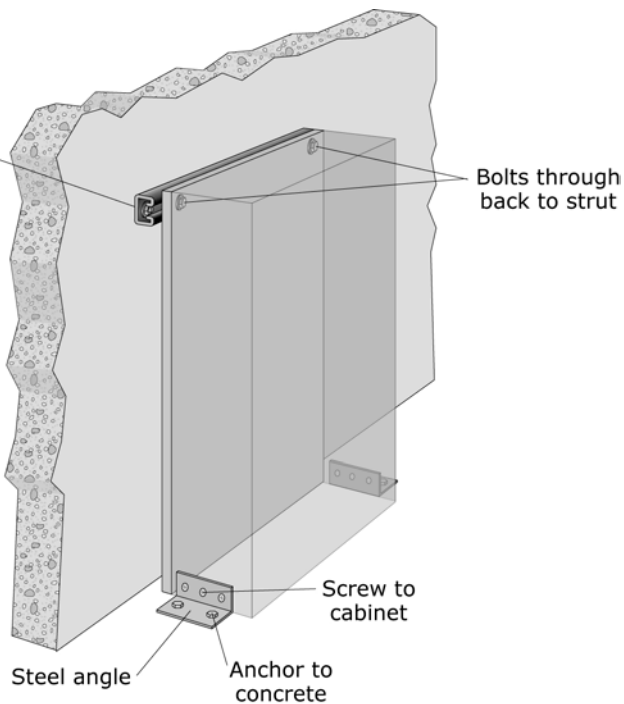
Figure 6.4.8.2-2 Wall anchorage for electrical panel; standard strut anchored to wall studs and panel anchored to strut (Photo courtesy of Maryann Phipps, Estructure).

## Mitigation Details

Strut against wall. Anchor to concrete or masonry with expansion anchors; anchor to studs with screws or toggle bolts. Verify that wall is capable of resisting loads imposed by all anchored equipment.



Alternate: anchor directly through base if unit is premanufactured for base anchorage and access is available



**Notes:** Equipment that is not tall and slender may be seismically anchored similar to Figure 6.4.1.1-6 or 6.4.1.1-7

Turn off all power to equipment before proceeding with any work

Figure 6.4.8.2-3 Free-standing electrical distribution panel (ER).



## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.9 LIGHT FIXTURES

#### 6.4.9.1 RECESSED LIGHT FIXTURES

This category covers recessed light fixtures that are part of a suspended ceiling grid. These may be lay-in fixtures in a suspended acoustic tile ceiling or recessed fixtures in other types of suspended ceilings such as gypsum board, plaster, or metal panels. Overhead light fixtures in a finished ceiling have often been damaged in past earthquakes; the fixtures may become dislodged from the ceiling or ceiling grid and fall unless they are tied to the grid and have independent support to the structure above.

#### TYPICAL CAUSES OF DAMAGE

- Recessed fixtures supported by a suspended ceiling without independent safety wires to the structure above can become dislodged and fall. Fixtures with proper safety wires may fall from the grid and dangle from the safety wire but will not threaten occupants.
- Unless secured to a properly braced ceiling grid, relative movement between the light fixture and the ceiling may damage the ceiling finishes, ceiling grid, wiring, or the light fixture. Heavy fixtures that are hung independently but not laterally braced may swing independent of the ceiling and damage the ceiling system.
- Unsecured lenses and bulbs may fall independent of the fixture and cause damage below.
- Most observed damage to recessed light fixtures in the U.S. has involved fixtures in suspended acoustic tile ceilings which do not have much inherent in-plane stiffness; damage to fixtures in gypsum board ceilings has been less common.

## Damage Examples



Figure 6.4.9.1-1 Numerous fluorescent fixtures dangling from electrical conduit; installed without safety wires in unbraced suspended acoustical ceiling and damaged in the 2010 magnitude-7 Haiti Earthquake. Loose bulbs, lenses, ceiling panels, diffusers and ducts also on the floor (Photo courtesy of Ayhan Irfanoglu, Purdue University).



Figure 6.4.9.1-2 Overhead lights with four vertical hangers to the structure. Unbraced acoustic ceiling system was damaged beyond repair in the 2001 magnitude-8.4 Peru Earthquake but none of the diffusers or lights fell because they had independent supports. Ceiling was demolished prior to photo (Photo courtesy of Eduardo Fierro, BFP Engineers).



Figure 6.4.9.1-3      Light fixture without adequate independent support dangling along one edge from ceiling grid, damaged in the 1994 magnitude-6.7 Northridge Earthquake (Photo courtesy of Degenkolb Engineers).





Figure 6.4.9.1-4 Light fixture without independent support dangling from conduit as a result of the 1994 Northridge Earthquake (Photo courtesy of Degenkolb Engineers).

## SEISMIC MITIGATION CONSIDERATIONS

- Requirements for recessed lighting fixtures may vary depending on requirements for the type of ceiling in which they are located. Recessed light fixtures may be found in any type of ceiling system. Requirements for suspended acoustic ceilings and suspended gypsum board ceilings are discussed below.
- For requirements for recessed fixtures in suspended acoustic tile ceilings, ASCE 7-10, , *Minimum Design Loads for Buildings and other Structures* (ASCE, 2010), references ASTM E580, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions* (ASTM, 2010); Section 4.4 covers conditions for ceilings weighing less than 2.5 psf in Seismic Design Category C and Section 5.3 covers ceilings weighing more than 2.5 psf in Seismic Design Category C and ceilings in Seismic Design Categories D, E and F. Per ASTM E580 Section 5.3 light fixture require the following:
  - lights must be positively attached to the ceiling grid with a minimum of two attachment devices capable of resisting 100% of the fixture weight in any direction. This is not required if the light has independent vertical and lateral support.
  - where the load carrying capacity of the cross runners is less than 16 lb/ft, supplementary hanger wires may be required for the ceiling grid. See discussion regarding the requirement for supplementary framing and supplementary hanger wires for the suspended ceiling grid under Section 6.3.4.1. Note also that intermediate duty or heavy duty grid is required for ceilings carrying light fixtures.
  - For fixtures weighing less than 10 lb, provide one #12 safety wire connected from the fixture housing to the structure above; wire may be slack.
  - For fixtures weighing from 10 lb to 56 lb, provide two #12 safety wires at diagonally opposite corners connected from the fixture housing (not the detachable end plates) to the structure above; wires may be slack.
  - For fixtures weighing more than 56 lb, these must be supported directly from the structure above by approved hangers. If the ceiling bracing can provide lateral restraint for such fixtures, they should be positively attached to the ceiling grid as noted above but supported with not less than four taut #12 wires. This requirement is also often taken to apply to large 4'x4' fixtures. Refer to Section 6.4.9.4 for heavy fixtures requiring independent vertical and lateral support.

- For acoustic tile ceilings, California schools require safety wires or independent vertical support for each light fixture, positive attachment from the light fixtures to the ceiling grid, and bracing for the ceiling grid that is adequate to resist the lateral loading from the ceiling, lights, and diffusers. DSA IR 25–5 *Metal Suspension Systems for Lay-in Panel Ceilings* (California Department of General Services, 2009c) provides details for lights in suspended acoustic ceiling grids. The requirements in DSA IR 25–5 differ slightly from ASTM E580: California schools require two safety wires on all fixtures under 56 pounds; require all 4 ft x 4 ft fixtures have a slack #12 safety wire at each corner, even if the fixture weight is less than 56 lb; and for fixtures weighing more than 56 lb, require they be independently supported by not less than four taut #12 wires, and that these wires be capable of supporting four times the weight of the fixture.
- Per ASCE 7–10, certain types of suspended ceilings with screw-attached gypsum board built at one level do not require special seismic details; these ceilings also do not require safety wires for light fixtures (see Section 6.3.4.3 for a discussion of exempt ceilings). The weight of recessed light fixtures in suspended gypsum board ceilings must be supported by main runners, supplementary framing supported by the main runners, or directly by the structure above. Neither the ceiling finish material nor the cross furring should be used to support light fixtures. The fixture should be positively attached with screws or other approved connectors to the ceiling grid. Requirements for California schools are in DSA IR 25–3 *Drywall Ceiling Suspension Conventional Construction–One Layer* (California Department of General Services, 2005b). For suspended gypsum ceilings built at multiple levels, or other types of heavy ceilings, seismic detailing and safety wires for lighting may be required; check applicable code provisions.
- International Code Council Evaluation Service has published AC184, *Acceptance Criteria for Attachment Devices for Recessed Lighting Fixtures (Luminaries) in Suspended Ceiling Systems* (ICC–ES, 2006), with information on attachments of light fixtures to suspended ceiling grids. The website located at <http://www.agi-seismic.com/code/ac184.html#> provides footage of lighting fixture failures where the lights are attached only with tie wires. A discussion of issues related to the code design provisions and the requirement for positive attachments is also provided. In some instances, where approved seismic fixture clamps (SFC) are used to anchor the lighting to a properly braced ceiling grid, the independent tie wires are not required.
- For existing construction where the ceiling grid is not adequately braced or not strong enough to provide lateral restraint for the lighting, splay wire bracing at each corner of the fixture can be used to provide horizontal restraint. Such bracing would also help

prevent swinging lights from damaging the surrounding ceiling. At a minimum, such fixtures should be retrofit with independent safety wires to prevent them from falling.

- Lenses and bulbs may require independent restraints to keep them from falling from the fixture.
- For fire rated ceiling assemblies, only fixtures and attachments with an approved fire rating may be used. Check with the manufacturer for approved systems. Some fixtures may require lead shielding or a fire-rated enclosure; check local code provisions.
- Do not attach lights to ducts, piping, or other nonstructural items in the ceiling plenum.

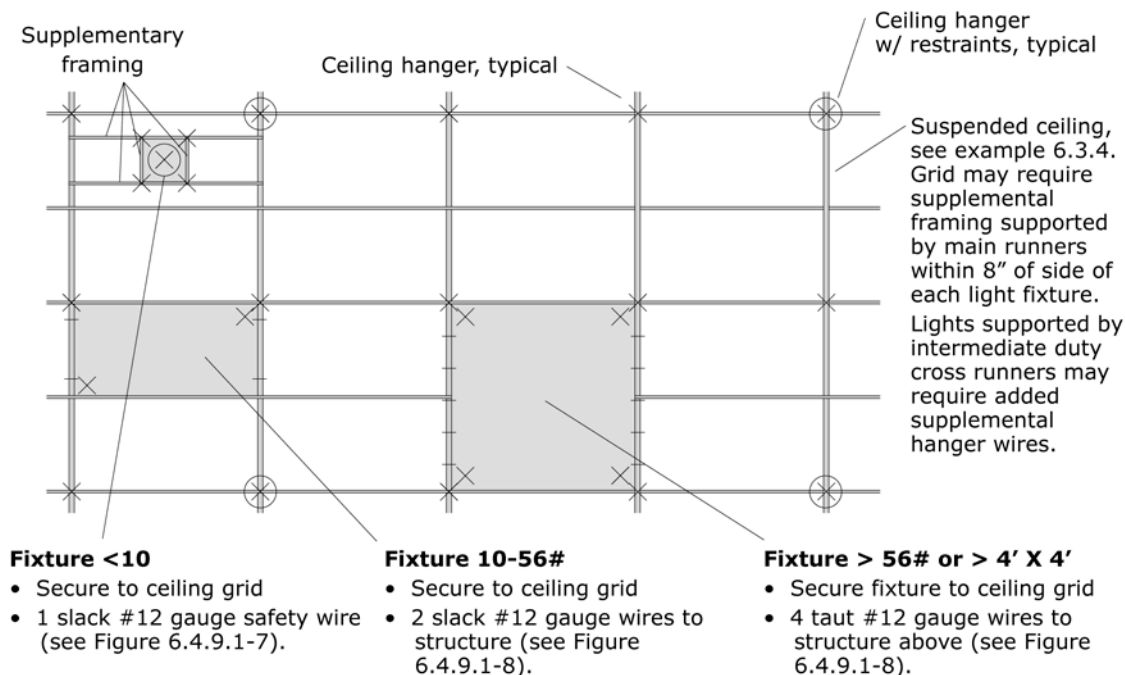
### Mitigation Examples



Figure 6.4.9.1-5 Example of light fixture with only one safety wire attached; the Salt Lake City schools require four wires for a fixture of this size and weight and also require tighter turns on the wire (Photo courtesy of Salt Lake City School District). Investigations in ceiling plenums often reveal missing wires.



## Mitigation Details



### Notes:

- Provide positive attachment from recessed fixture to braced ceiling grid (must resist 100% of weight in any direction).
- Provide 1, 2 or 4 #12 gauge wires to structure depending on weight of fixture (< 10#, 10# - 56#, > 56#), respectively.
- Provide engineering of vertical and lateral supports for heavy fixtures or where existing ceiling not adequately braced.
- For exposed fluorescent light bulbs or fixture lenses subject to falling, secure in place with 2 wires that wrap beneath the lens or bulbs and attach securely to the fixture.
- Avoid locating light fixtures at floating edges of ceiling unless detailed to move with ceiling grid. Alternatively, install fixture on wall independent of ceiling and provide required ceiling clearance all around.
- Proprietary clips are available that may eliminate the need for safety wires; check jurisdiction for pre-approved details.

Figure 6.4.9.1-6 Schematic plan of recessed lights in suspended acoustic ceiling (PR).

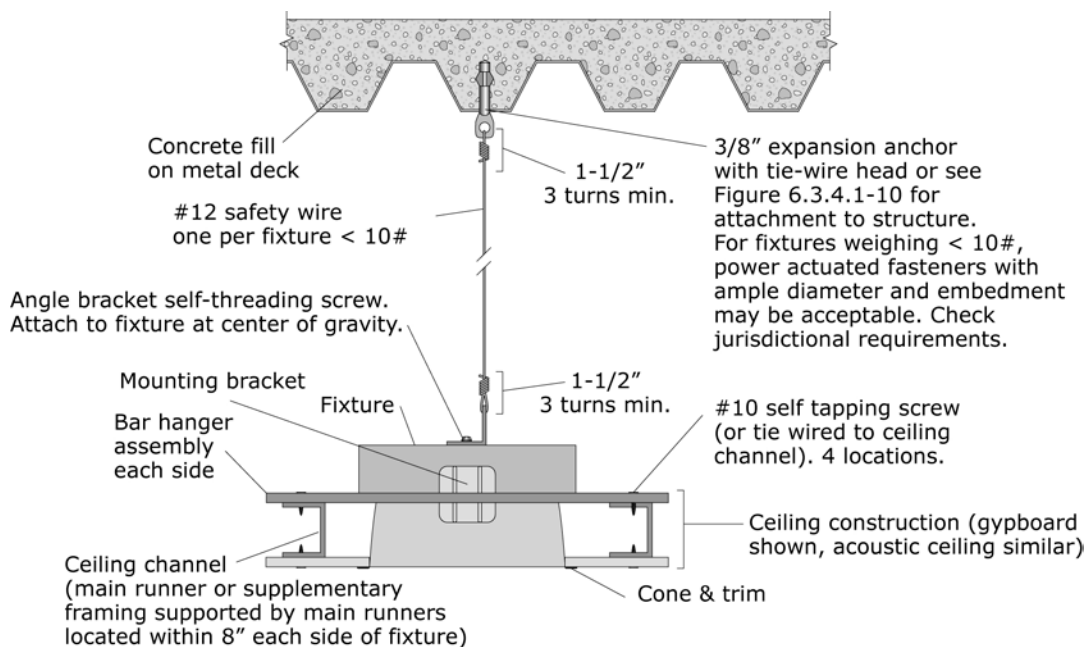


Figure 6.4.9.1-7 Recessed light fixture in suspended ceiling (fixture weight &lt; 10 pounds) (PR).

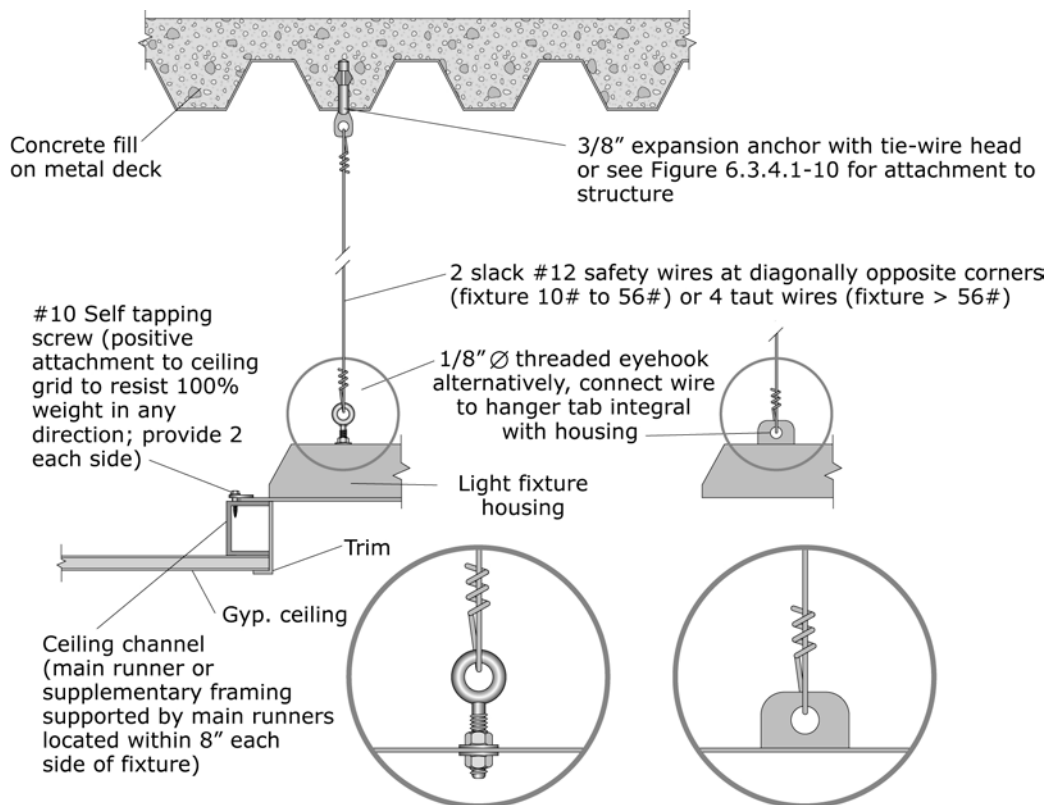


Figure 6.4.9.1-8 Recessed light fixture in suspended ceiling (fixture weight 10 to 56 pounds) (PR).

## 6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

### 6.4.9 LIGHT FIXTURES

#### 6.4.9.2 SURFACE-MOUNTED LIGHTING

This category covers surface-mounted light fixtures that are overhead in a finished ceiling. The term surface-mounted refers to a range of conditions; in some cases the fixture and housing are entirely below the ceiling surface, in other cases part of the housing is recessed above the bottom of the ceiling. Overhead fixtures may also be surface-mounted on a wall. Damage to overhead lighting has occurred frequently in past earthquakes; the fixtures become dislodged from the ceiling or ceiling grid and fall unless they are tied to the grid or have independent support to the structure above.

#### TYPICAL CAUSES OF DAMAGE

- Surface lighting that is not equipped with independent safety wires may fall to the floor. Lighting with proper safety wires may fall from the ceiling and dangle from the safety wires but will not pose a safety risk to occupants.
- Unless secured to a properly braced ceiling grid, relative movement between the light fixture and the ceiling may damage the ceiling finishes, ceiling grid, wiring, or the light fixture.
- Unsecured lenses and bulbs may become dislodged and fall to the floor even where the fixture is restrained. This may occur with both ceiling and wall mounted surface lighting.
- Most observed damage to light fixtures in the U.S. has involved fixtures in suspended acoustic tile ceilings which do not have much inherent in-plane stiffness; damage to fixtures mounted in or on gypsum board ceilings has been less common.

## Damage Examples

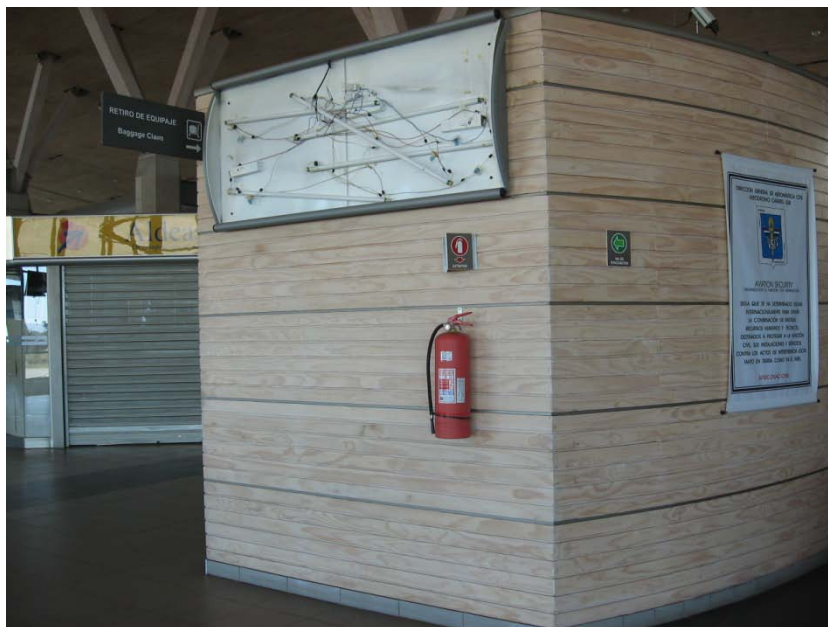


Figure 6.4.9.2-1 Numerous failures of ceilings and lights were observed at the Concepción airport in the 2010 magnitude-8.8 Chile Earthquake. Photo shows surface-mounted fixture on wall that remained in place but the lens fell and the bulbs were dislodged (Photo courtesy of Rodrigo Retamales, Rubén Borosc hek & Associates).





Figure 6.4.9.2-2

Overhead surface-mounted fixture anchored to underside of concrete slab damaged in the 2010 Chile Earthquake. Back of fixture housing remained anchored to the concrete slab above and the bulbs remained in place but the lens and sides of housing fell indicating that internal connections in the fixture were inadequate (Photos courtesy of Rodrigo Retamales, Rubén Boroschek & Associates).

## SEISMIC MITIGATION CONSIDERATIONS

- As referenced in Section 13.5.6 of ASCE 7–10, *Minimum Design Loads for Buildings and other Structures* (ASCE, 2010), ASTM E580, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions* (ASTM, 2010), requires that surface-mounted fixtures in a suspended acoustic ceiling shall be attached to the ceiling suspension system with positive clamping devices that completely surround the supporting members. Safety wires are required between the clamping device and the adjacent ceiling hanger or to the structure above. The weight of the fixture shall not exceed the design carrying capacity of the supporting members. One, two, or four safety wires are required from the fixture housing to the structure above. These requirements for safety wires are the same as for recessed fixtures and are as follows:
  - For fixtures weighing 10 pounds or less, provide one slack safety wire
  - For fixtures weighing between 10–56 pounds, provide two slack safety wires at diagonally opposite corners
  - For fixtures weighing more than 56 pounds, provide independent support to the structure above. For many fixtures, this can be satisfied with 4 taut wires. Heavy or specialty fixtures, such as operating room lights in a hospital, may require engineered support and bracing details such as those shown in Section 6.4.9.4.
- For suspended acoustic ceilings, ASTM E580 has other requirements related to the grid itself. Intermediate or heavy duty ceiling grid is required where lights will be supported and supplementary ceiling framing and supplementary hanger wires may be required adjacent to fixtures. Lateral restraint for lighting is assumed to be provided by the ceiling grid so the design of the grid must account for the overall weight of all the attached lighting and mechanical registers. See Section 6.3.4 for additional information regarding ceilings.
- Per ASCE 7–10, certain types of suspended ceilings with screw-attached gypsum board built at one level do not require special seismic details; these ceilings also do not require safety wires for light fixtures (see Section 6.3.4.3). The weight of surface-mounted fixtures must be supported by main runners, supplementary framing supported by the main runners, or directly by the structure above. Neither the ceiling finish material nor the cross furring should be used to support light fixtures. The fixture should be positively attached with screws or other approved connectors to the ceiling grid. Requirements for California schools are in DSA IR 25–3 *Drywall Ceiling Suspension Conventional Construction–One Layer* (California Department of General

Services, 2005b) and read “Surface-mounted fixtures shall be attached to a main runner with a positive clamping device made of material with a minimum of 14 gage. Rotational spring clamps do not comply.” For suspended gypsum ceilings built at multiple levels, or other types of heavy ceilings, seismic detailing and safety wires may be required; check applicable code provisions.

- International Code Council Evaluation Service has published Acceptance Criteria AC184 (ICC-ES, 2006) with information on attachments of light fixtures to suspended ceiling grids. The website located at <http://www.agi-seismic.com/code/ac184.html> provides footage of lighting fixture failures where the lights are attached only with tie wires. A discussion of issues related to the code design provisions and the requirement for positive attachments is also provided. In some instances, where approved seismic fixture clamps are used to anchor the lighting to a properly braced ceiling grid, independent tie wires are not required. Check for pre-approved details for such devices in the applicable jurisdiction.
- For surface-mounted fixtures in existing buildings where the ceiling grid is unbraced, such fixtures should be retrofit with safety wires at a minimum to prevent them from falling. Providing independent lateral bracing for the fixture may reduce the potential for the light to damage an existing unbraced ceiling.
- For fire rated ceiling assemblies, only fixtures and attachments with an approved fire rating may be used. Check with the manufacturer for approved systems. Some fixtures may require lead shielding or a fire-rated enclosure; check local code provisions.
- Do not attach lights to ducts, piping, or other nonstructural items in the ceiling plenum.

## Mitigation Examples

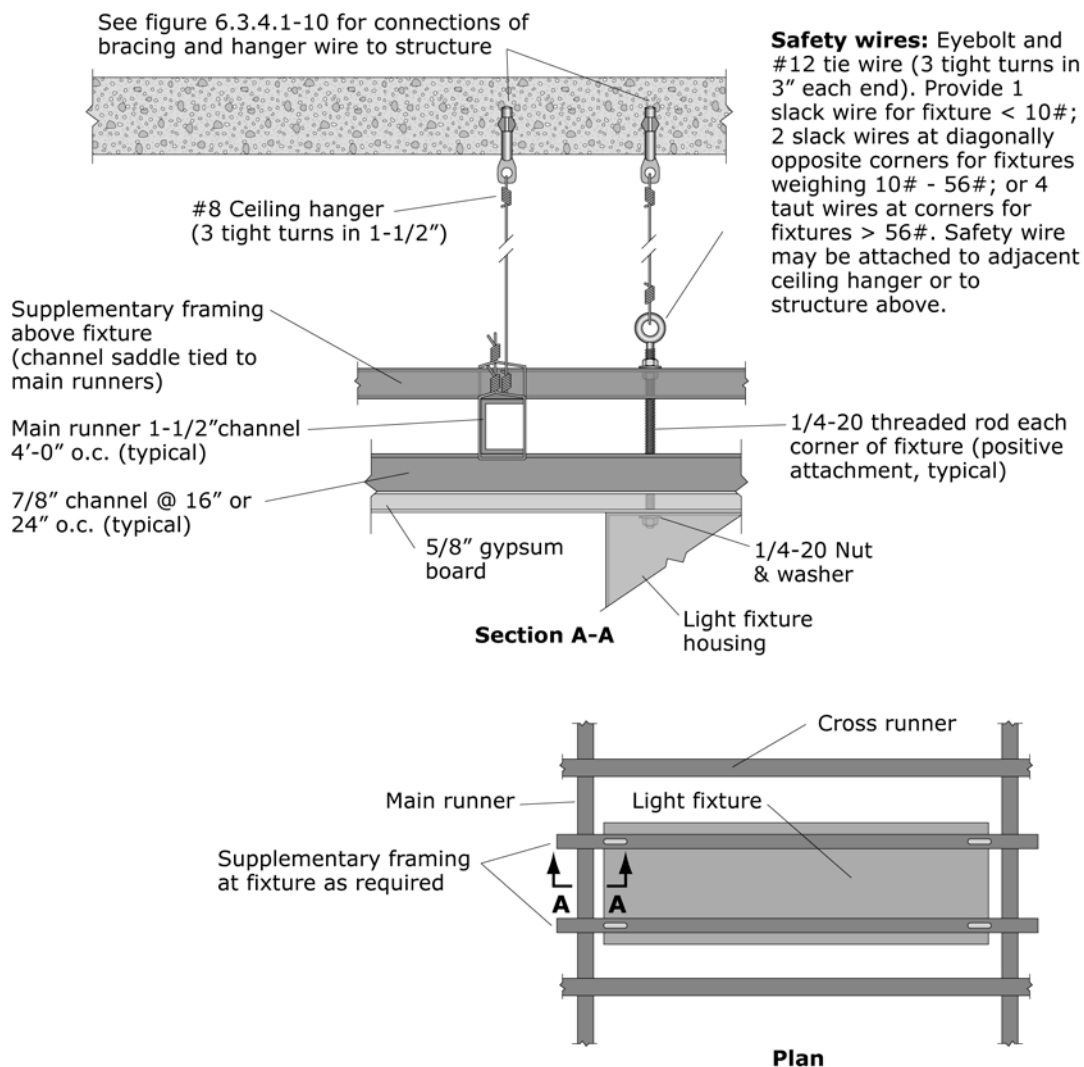


Figure 6.4.9.2-3

Independent vertical support for surface-mounted light fixture in suspended gypsum board ceiling located in California hospital. Eye hook and slack wire from fixture is tied to concrete slab above. The rigid bracing in the photos is attached to the ceiling grid, not the light fixture (Photos courtesy of Maryann Phipps, Estructure).



## Mitigation Details



**Note:** Surface-mounted fixtures shall be attached to ceiling suspension systems with screws or positive clamping devices. Safety wires (1, 2 or 4) are required in suspended acoustic lay-in tile ceilings depending on the size and weight of the fixture; safety wires may be required in other ceiling types as well. Weight of fixture shall not exceed design carrying capacity of the supporting members; supplementary framing and additional hanger wires may be required. Gypsum board ceiling shown in details; although some gypsum ceilings may be exempt from the seismic detailing requirements and may not require the safety wires shown.

Figure 6.4.9.2-4 Surface-mounted fixture below suspended ceiling grid (PR).